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ENERGY CONSUMPTION GUIDE 74

Energy consumption in continuous steel reheating furnaces

- Summary of industry energy performance
- Benchmarking for self-assessment
- Actions to minimise energy consumption

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ENERGY CONSUMPTION GUIDE 74

STEEL REHEATING

The UK steel industry reheats approximately 17.2 million tonnes of steel feedstock prior to rolling. Continuous reheating furnaces are responsible for almost 85% of this total (14.6 million tonnes), the remainder being reheated, or partly reheated, in batch type furnaces - mainly soaking pits.

Total energy consumption for reheating is about 32.6 PJ. Of this, 28.6 PJ is used by continuous reheating furnaces and 4 PJ by batch furnaces. The main fuels used are natural gas (51% of the total) and process gases, with gas oil and fuel oil accounting for little more than 10%.

The average specific energy consumption for continuous furnaces is 1.96 GJ/tonne of steel charged. The product yield, based on the charged weight and the finished rolled product weight, is 94.8%.

THE SURVEY

In 1996, the Department of the Environment, Transport and the Regions commissioned a survey to ascertain the factors influencing reheating furnace energy performance. Questionnaires were devised to elicit information on furnace design, waste heat recovery systems, control facilities, operating practices, energy use and production levels. The survey was managed by ETSU to ensure confidentiality, and the information gained was independently analysed by British Steel's Swinden Technology Centre.

Twenty-four completed questionnaires were returned, covering 33 continuous steel reheating furnaces. The findings are considered to be representative of the UK steel reheating industry as a whole.

SURVEY FINDINGS

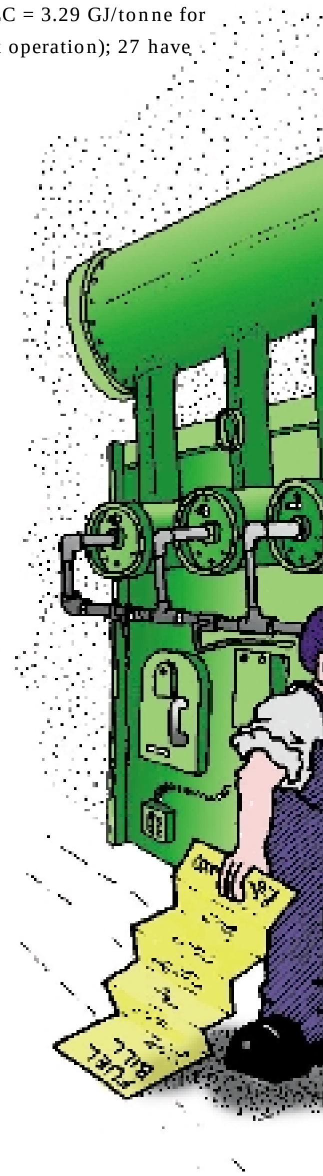
General Information Report 57 contains details of the survey findings.

The essential points are:

- Specific energy consumption (SEC), or energy consumed per tonne of throughput, varies from 1.13 GJ/tonne to 10.99 GJ/tonne, averaging 1.9 GJ/tonne for top-fired furnaces and 2.0 GJ/tonne for top-and-bottom-fired units.

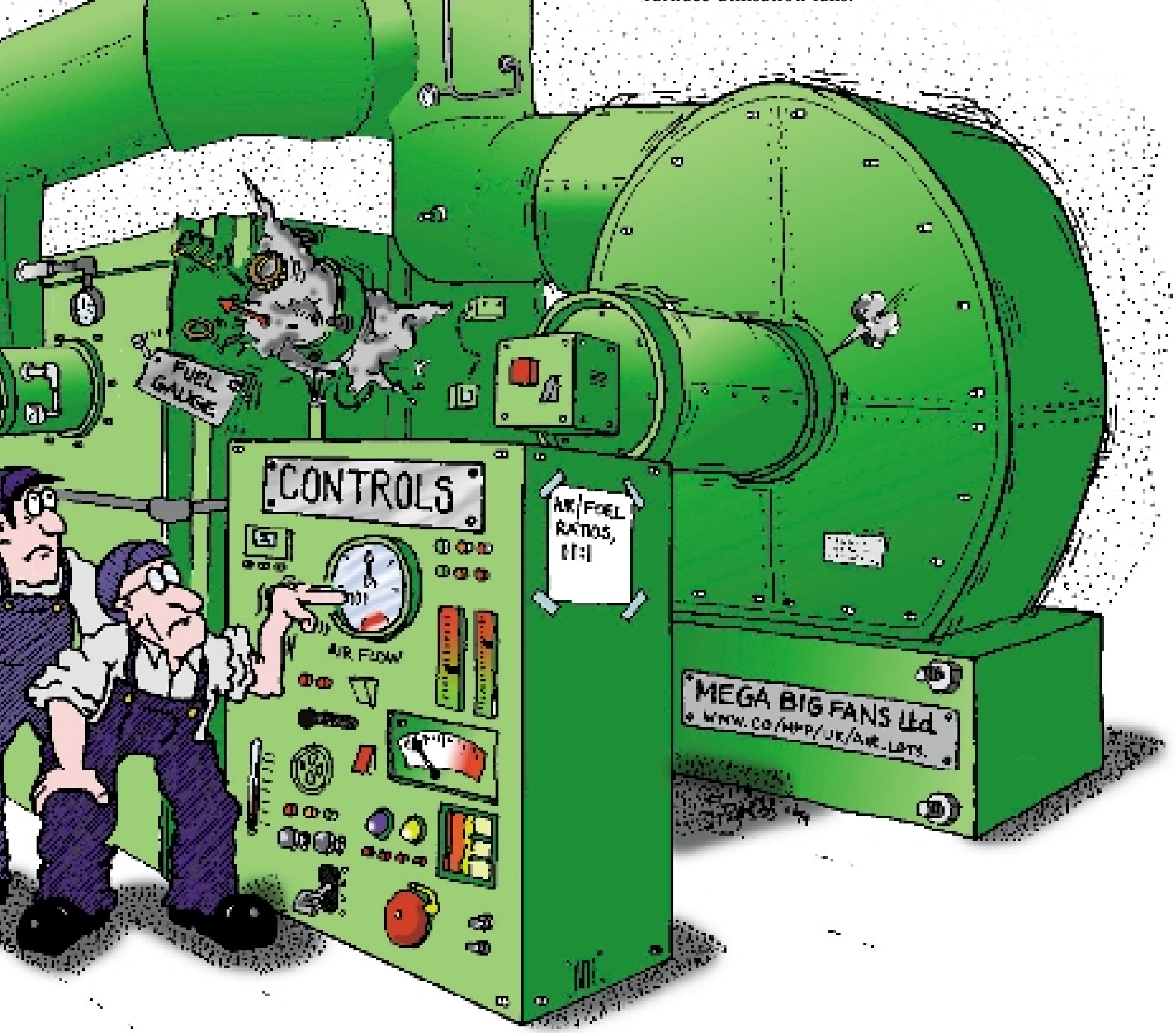
- Nearly every furnace employs some form of heat recovery. Three have regenerative burners (average SEC = 1.9 GJ/tonne); one has self-recuperative burners (SEC = 3.29 GJ/tonne for less than 60 hours/week operation); 27 have external recuperators (average SEC = 2.02 GJ/tonne).

- Twenty-four of the furnaces incorporate passive or unfired stock recuperation zones in which heat from the products of combustion is transferred to the stock.



STEEL REHEATING

- Installed maximum thermal input ranges from 15 GJ/hour to around 470 GJ/hour.
- Three furnaces employ hot charging techniques.
- All furnaces have some form of automatic zone temperature control, burner air/fuel ratio control, and pressure control. All but ten furnaces incorporate computer-based control systems.
- Only one furnace is fitted with low-NO_x burners.
- The mixture of fuels used indicates that about 50% of furnaces have a dual-fuel capability.
- Eleven of the furnaces report the use of low thermal mass materials as part of the roof or walls.
- Production capabilities range from 5 tonnes/hour to 250 tonnes/hour. Furnaces with a throughput of more than 50 tonnes/hour tend to have lower SEC consumption levels. Specific energy consumption increases as furnace utilisation falls.



BENCHMARKING FURNACE ENERGY USE

Individual furnaces are unique in their design and operation, which makes it difficult to set industry-wide benchmarks for energy use. You will therefore need to carry out your own benchmarking exercise, following the steps set out below.

STEP 1: EVALUATE YOUR PRESENT PERFORMANCE

Your first step is to prepare a plot of energy use against production rate using information gleaned either from historical records or from your energy monitoring and targeting system[1].

The example shown in Fig 1 for a walking beam furnace plots energy use in GJ per shift against throughput in tonnes charged to the furnace per shift. It is equally acceptable to use a working day or a working week (excluding light-up shifts) as the period for consideration, provided this is consistent with the period of energy use and greater than the typical residence time of stock in the furnace.

The plot in Fig 1 shows a scatter of points about a line of 'best fit'. This line is determined from a simple linear regression of the data. The scatter can usually be explained by variations in operational procedures - delays, steel discharge temperatures etc. - but points that lie well above the line of best fit could indicate periods of poor performance. Investigate these to determine their cause.

All points lying below the line of best fit represent periods when energy performance has been better than average. Those furthest below the line represent the best energy performance possible using current operating procedures. Adopt these as a first target for minimum energy use.

[1] Advice on assessing furnace performance and the potential for energy saving can be obtained from professional bodies and organisations and also from the Energy Efficiency Best Practice Programme.

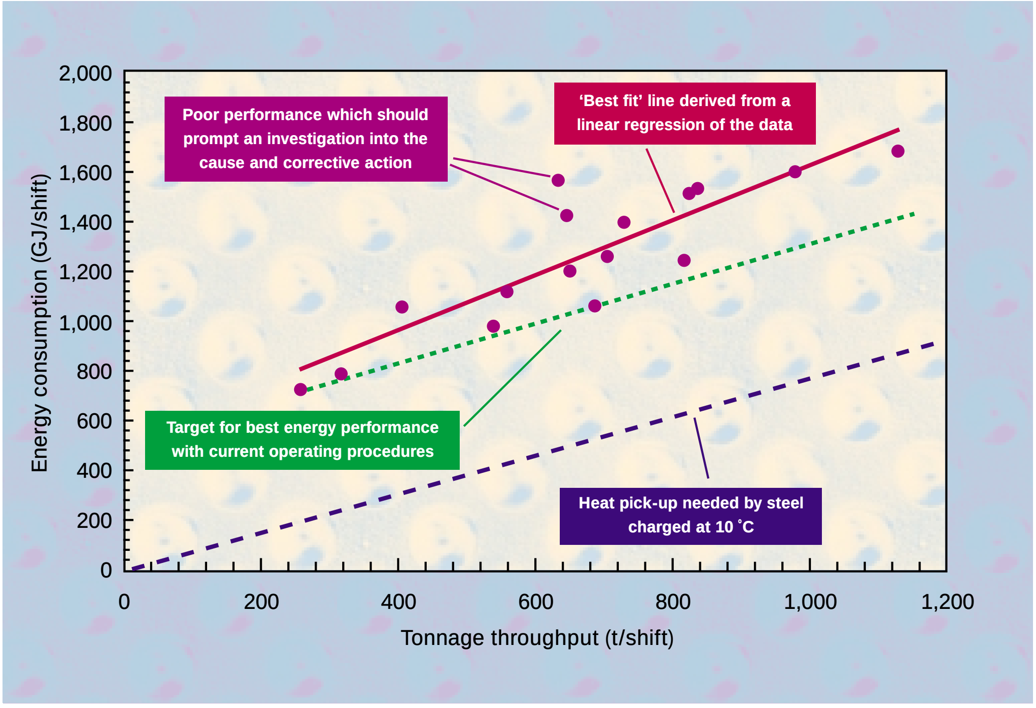


Fig 1 Furnace energy consumption vs throughput

BENCHMARKING FURNACE ENERGY USE

Fig 2 analyses the same data in a different way, plotting SEC against throughput. In this case, the line of best fit is a curve, with higher SEC levels at low tonnage throughputs and lower SEC levels at high tonnage throughputs. Although this analysis can also be used to highlight good and poor performance, the energy saving potential is less obvious than when considering energy use and productivity on a time basis.

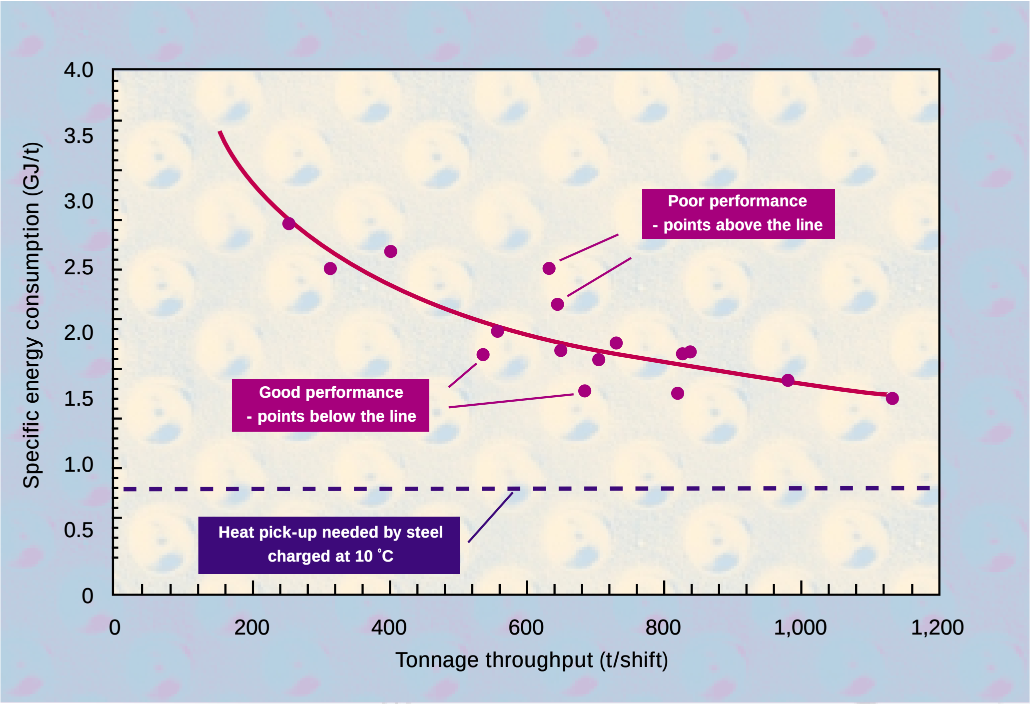
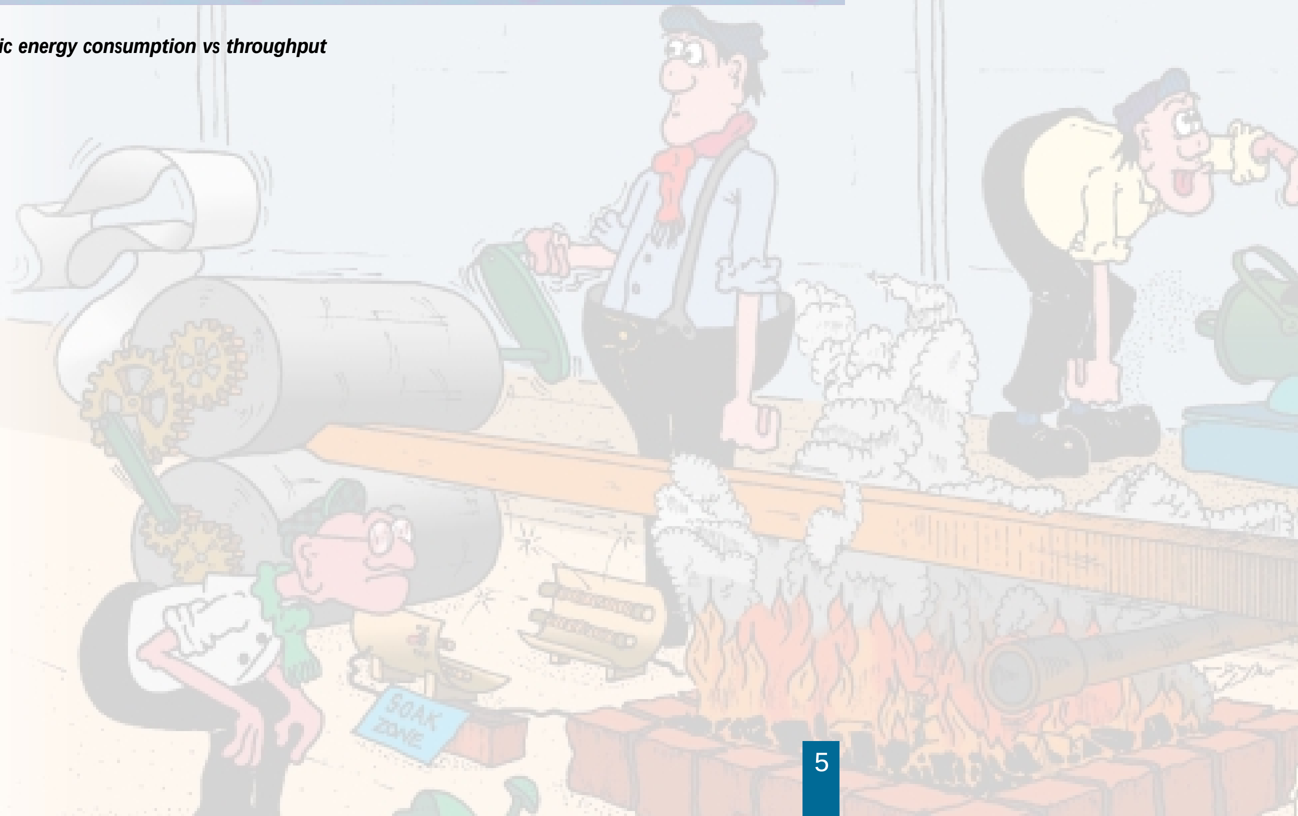


Fig 2 Furnace specific energy consumption vs throughput



ENERGY USE AND COSTS

STEP 2: USE THE BENCHMARK EQUATION TO MINIMISE ENERGY USE

Furnace fuel consumption during productive periods depends on the heat pick-up by the steel, the energy losses from the furnace and the energy lost in waste gases. The equation for this relationship, which represents a straight line, is as follows:

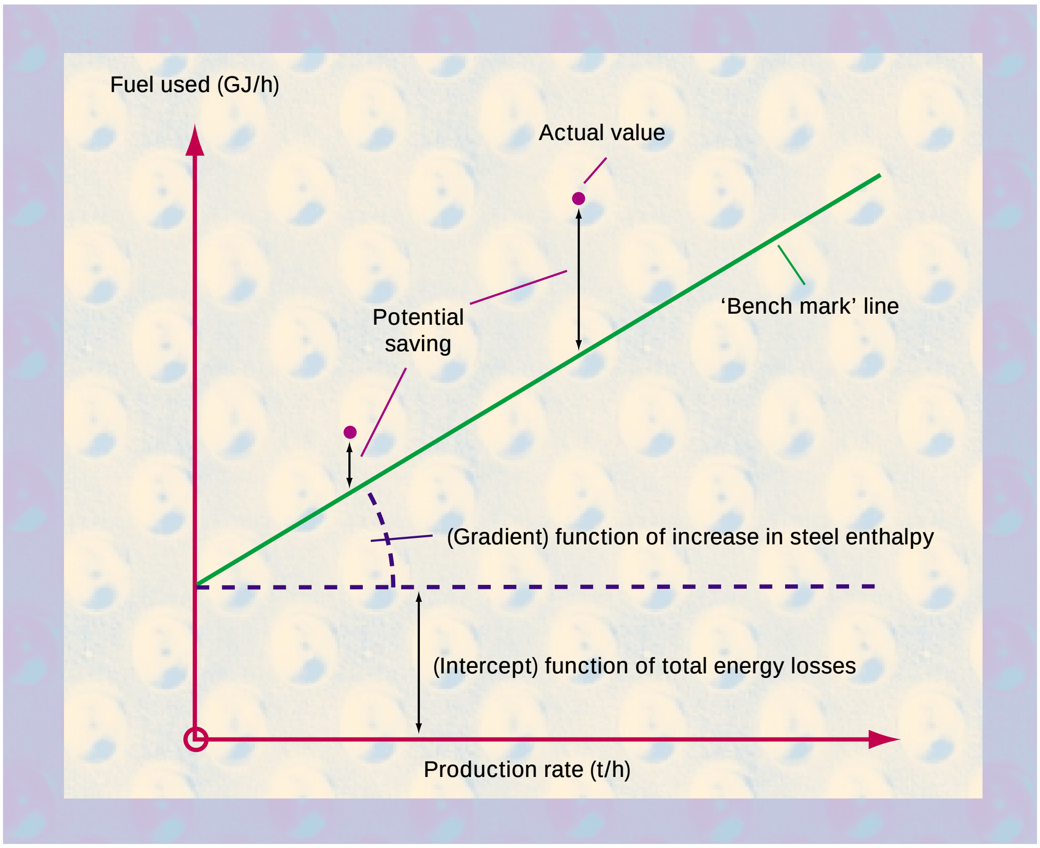
This equation is represented diagrammatically in Fig 3. The gradient of the benchmark line is determined by the increase in the heat content of the steel, i.e. its increase in enthalpy (GJ/tonne), between being charged and discharged. The intercept of the line is determined by total energy losses, i.e. energy lost through the furnace structure and in the cooling water.

Fuel use (GJ/shift) =

$$\left\{\frac{\text{Increase in heat content of steel (GJ / tonne)}}{\text{Furnace combustion efficiency } (\eta)\ (\%)} \times 100\right\} \times \text{Production rate (tonnes / shift)} + \left\{\frac{\text{Total energy losses (GJ / shift)}}{\text{Furnace combustion efficiency } (\eta)\ (\%)} \times 100\right\}$$

where total energy losses consist of structural energy losses and water cooling losses.

Fig 3 Benchmarking to minimise furnace energy use



ENERGY USE AND COSTS

You can calculate the appropriate benchmark for minimum energy use in your reheating furnace by substituting appropriate values into the equation. These values must be those expected for a well maintained furnace with good operating practices. They can be obtained from Tables 1 - 4.

Table 1 gives values for the heat pick-up needed by the steel, i.e. its increase in enthalpy, for a range of charge and discharge temperatures.

Table 2 gives values for furnace combustion efficiency for a range of exhaust gas and combustion air pre-heat temperatures. Choose a value that reflects achievable exhaust gas and air pre-heat temperatures based on the specifications of your recuperator.

Table 3 gives values for transmitted structural energy losses for top-fired pusher and walking hearth furnaces and for top-and-bottom-fired pusher and walking beam furnaces. Select the value that is appropriate to your furnace type and dimensions. Add to this value the relevant water cooling energy loss given in Table 4.

NB The losses in Tables 3 and 4 are in GJ/hour. If your calculation is based on shifts rather than hours, adjust the values accordingly.

You can also set a target for specific energy consumption by dividing benchmark energy use by tonnage throughput.

STEP 3: ASSESS YOUR POTENTIAL ENERGY SAVINGS

Plot your actual values for energy use against production rate on the benchmark line you have constructed. You can now estimate the savings potential at each tonnage throughput rate, as shown in Fig 3.

Table 1 Value of steel enthalpy (GJ/tonne)

Mean bulk temperature of steel discharged (°C)	Mean bulk temperature of steel charged (°C)					
	10	50	200	400	600	800
1,200	0.811	0.793	0.719	0.605	0.468	0.264
1,220	0.824	0.806	0.732	0.618	0.481	0.277
1,240	0.837	0.819	0.745	0.631	0.494	0.290
1,260	0.850	0.832	0.758	0.644	0.507	0.303
1,280	0.863	0.845	0.771	0.657	0.520	0.316
1,300	0.876	0.858	0.784	0.670	0.533	0.329

Figures are based on a mild steel grade (BSO80A20) but are approximately valid for most other commonly processed alloy and carbon steel grades.
For austenitic stainless steels (300 series) multiply the figures given by 0.87 to give an approximate value.
Interpolation of the figures within the table is acceptable.
Heat release due to scale formation has been ignored.

BENCHMARKING FURNACE ENERGY USE

Table 2 Value of furnace combustion efficiency (%)

Exhaust gas temperature (°C)	Combustion air pre-heat temperature (°C)						
	20	200	300	400	600	800	1,000
600	65.5	71.7	75.3	78.9	-	-	-
700	61.0	67.2	70.8	74.4	-	-	-
800	56.3	62.5	66.1	69.7	77.4	-	-
900	51.6	57.8	61.4	65.0	72.7	-	-
1,000	46.8	52.7	56.6	60.2	67.9	75.3	-
1,100	42.0	48.2	51.8	55.4	63.1	70.5	-
1,200	37.0	43.2	46.8	50.4	58.1	65.5	73.4
1,300	32.0	38.2	41.8	45.4	53.1	60.5	68.4

Combustion air temperature is that measured at the burner, not on exit from the recuperator.
Exhaust gas temperature is measured on exit from the furnace.
Values for combustion efficiency are based on the gross calorific value for natural gas and combustion with 9.5% excess air (giving 2% oxygen in the dry exhaust gas). Combustion with 28% excess air (5% oxygen in the dry exhaust gas) reduces combustion efficiency by approximately 3%. Interpolation of the figures within the table is acceptable.
The figures can be used for other fuels with an error of up to 6%.

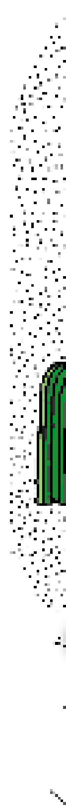
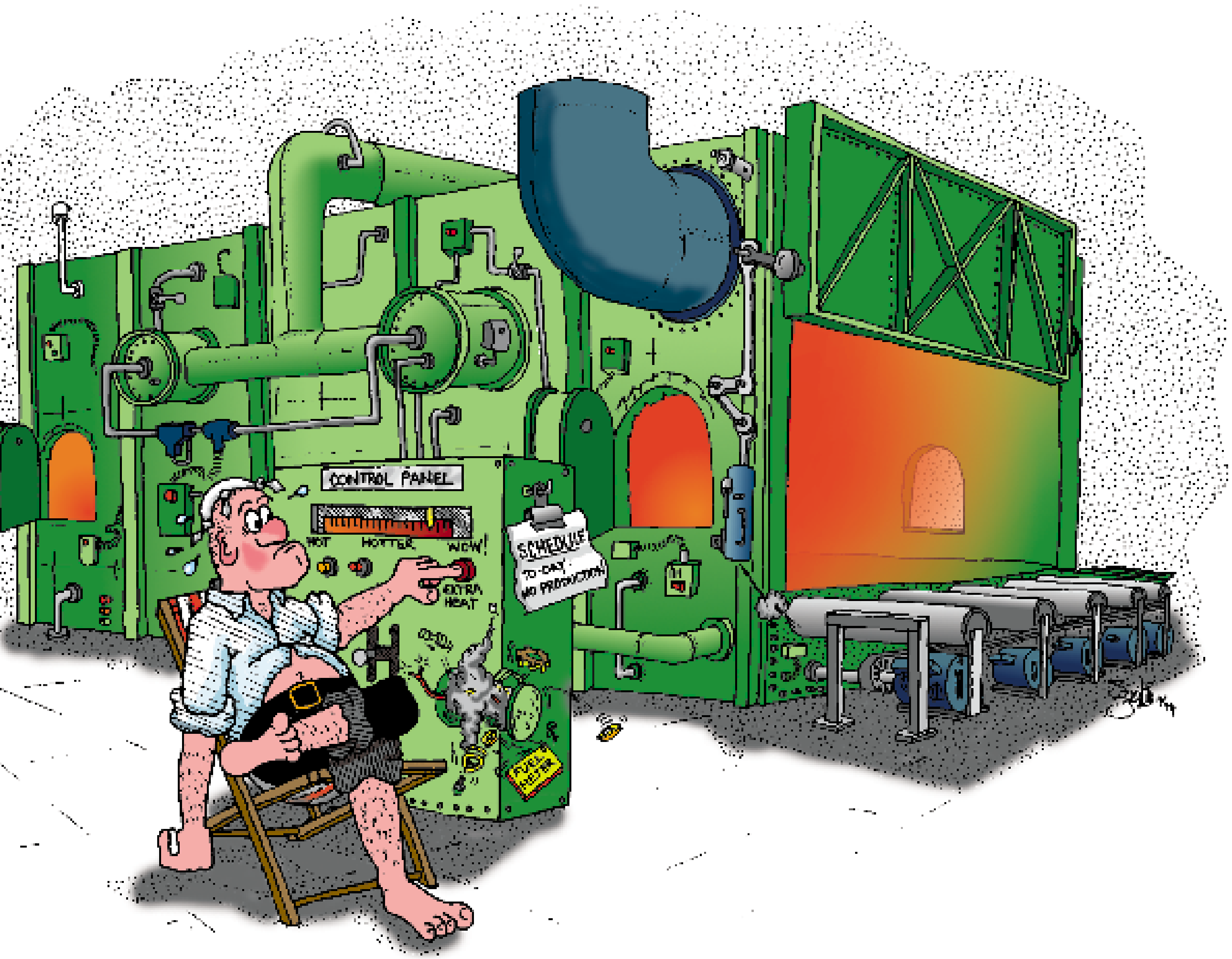


Table 3 Value of transmitted structural energy losses (GJ/hour)

Furnace width (m)	Furnace length (m)					
	10	15	20	30	40	50
Top-fired pusher and walking hearth furnaces						
10	1.1	1.5	2.0	2.9	3.8	4.7
12	1.3	1.8	2.3	3.4	4.4	5.5
14	1.4	2.0	2.7	3.9	5.1	6.3
16	1.6	2.3	3.0	4.4	5.7	7.1
18	1.8	2.6	3.3	4.8	6.4	7.9
20	2.0	2.8	3.7	5.3	7.0	8.7
Top-and-bottom-fired pusher and walking beam furnaces						
10	1.2	1.9	2.4	3.5	4.6	5.6
12	1.6	2.2	2.8	4.0	5.3	6.5
14	1.8	2.5	3.2	4.5	5.9	7.3
16	2.0	2.8	3.5	5.1	6.6	8.1
18	2.2	3.1	3.9	5.6	7.3	8.9
20	2.4	3.3	4.3	6.1	7.9	9.7

The figures are those expected from a well insulated furnace with an average outside wall temperature of 100°C. This is equivalent to a heat loss of 1.06 kW/m^2 (0.0038 $GJ/h/m^2$). Energy losses by radiation through openings (doors, sight holes, etc.) have been ignored.

BENCHMARKING FURNACE ENERGY USE



BENCHMARKING FURNACE ENERGY USE

Table 4 Value of water cooling energy losses

Type of furnace	Energy loss (GJ/h/m length of furnace)
Top-fired pushers with solid refractory hearth	0.0
Top-fired pushers with water-cooled hearth skids	0.2
Walking hearth	0.0
Top-and-bottom-fired pusher	0.3
Walking beam	0.4

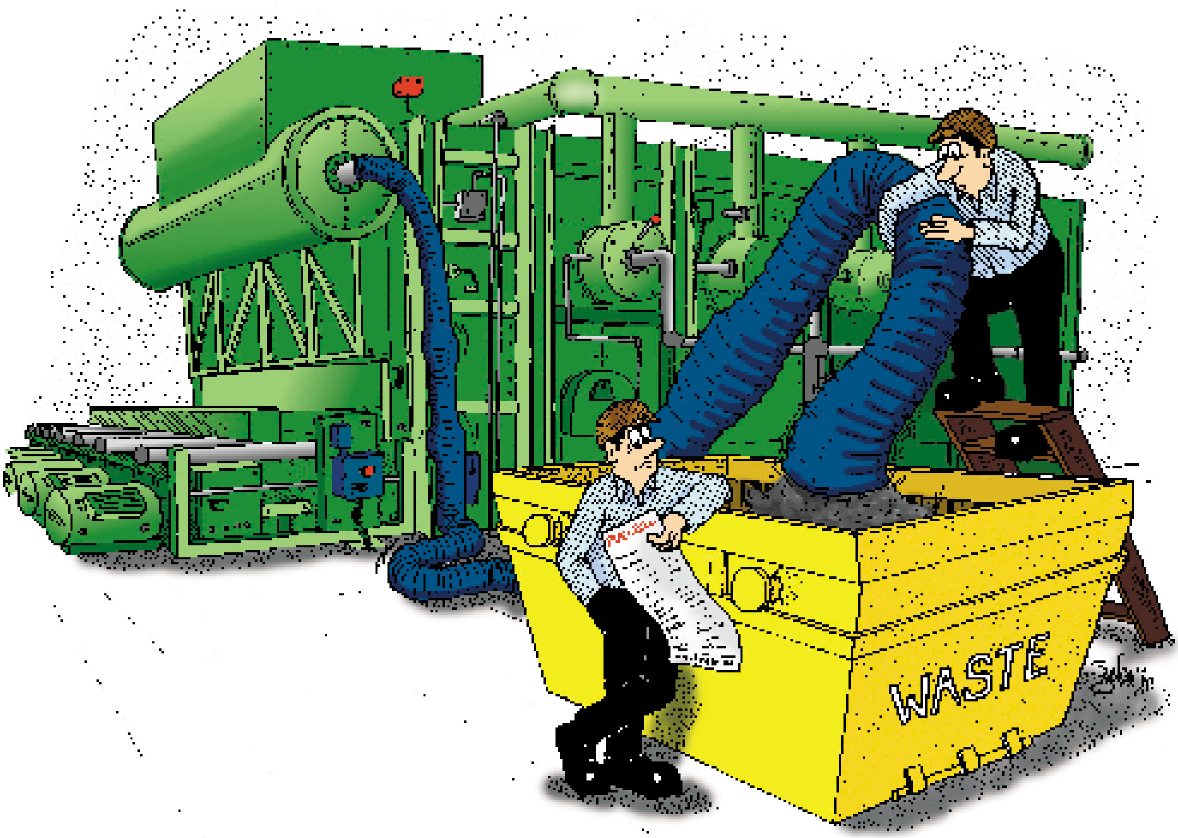
The energy losses per metre length of furnace are those expected from a well-insulated system with 100% insulation coverage.

STEP 4: DRAW UP AN ACTION PLAN TO REDUCE ENERGY USE

There are five main areas in which you may be able to minimise your energy consumption. The specific actions you can take are summarised in Table 5, together with the savings that can potentially be achieved by implementing energy saving techniques.

Consider each item in turn and decide whether its implementation is an option on your furnace. In each case give full consideration to:

- furnace design;
- plant layout;
- upstream and downstream activities and production rates;
- production schedules;
- rolling mill requirements;
- metallurgical requirements.



BENCHMARKING FURNACE ENERGY USE

Table 5 Actions to minimise energy consumption

Possible actions	Potential savings	Considered	Actioned
Minimise heat pick-up by steel			
■ Ensure steel discharge temperatures are at the minimum that is commensurate with rolling requirements. ■ Use computer controls to optimise furnace/zone temperature settings for steel throughput rates. ■ Maximise steel charging temperatures, either by establishing a direct link with the caster or by using insulated hot boxes.	Up to 0.4 GJ/tonne		
Minimise heat content of exhaust gases leaving furnace			
■ Maximise stock recuperation by maximising the length of unfired zones and therefore the area for heat transfer. ■ Minimise the air/fuel ratio. If metallurgical conditions allow, aim for 2% oxygen in the dry exhaust gases. ■ Optimise furnace temperature settings. ■ Use pressure control to prevent hot gas leaving the furnace through doors and openings.	Up to 5%		
Maximise heat content of pre-heated combustion air			
■ Maximise heat recuperation from exhaust gases using:			
- external recuperators;	Up to 30%		
- self-recuperative burners;	Up to 30%		
- regenerative burners.	Up to 50%		
■ Use oxygen trim control to optimise the air/fuel ratio. ■ Use pressure control to prevent the ingress of cold air to the furnace. ■ Avoid recuperator leaks. ■ Insulate hot air mains.			

BENCHMARKING FURNACE ENERGY USE

Table 5 Actions to minimise energy consumption (continued)

Possible actions	Potential savings	Considered	Actioned
Minimise heat loss through furnace structure			
■ Keep the outside temperature of the furnace to a minimum. Aim for an average of less than 100°C by: - optimising furnace temperature settings; - using low thermal mass insulation with a low thermal conductivity.	Up to 10%		
■ Maximise the insulation of water-cooled components. Aim for a 100% coverage.			
■ Minimise the area of openings - doors, sight holes etc. Ensure good door seals and minimum opening times.			
■ Minimise heat loss when the furnace is shut down at weekends by closing doors and sealing the furnace. This will also help to minimise fuel use during light-up.			
Optimise control and operational procedures			
■ Use pressure control to prevent hot gas leaving the furnace and cold air entering.			
■ Use direct measurement of stock temperature to control furnace temperatures.	Up to 4.5%		
■ Use optimum air/fuel ratio settings and oxygen trim control.	Up to 5%		
■ Use computer-based systems to predict stock temperatures for zone temperature control (delay strategies).	Up to 10%		
■ Schedule production to maximise furnace utilisation.			

The Department of the Environment, Transport and the Regions' Energy Efficiency Best Practice Programme provides impartial, authoritative information on energy efficiency techniques and technologies in industry, transport and buildings. The information is disseminated through publications, videos and software, together with seminars, workshops and other events. Publications within the Best Practice Programme are shown opposite.

Further information

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